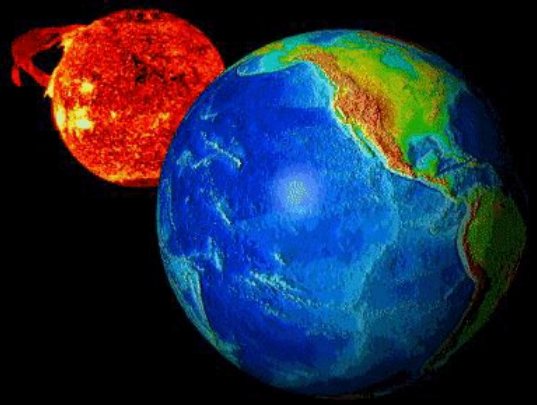
The Space Environment and its Impacts on Military Operations

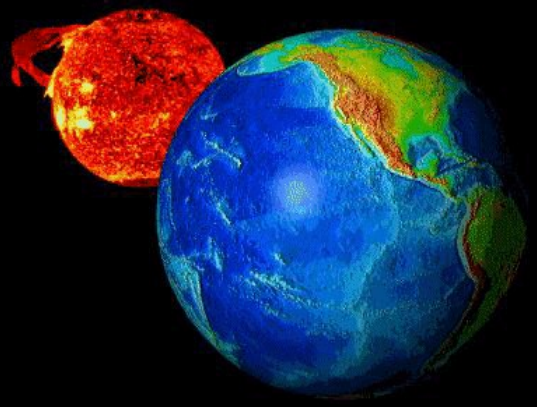
Business of Space
5 Dec 2001

Space Operations Scho



Overview

- Space Environment Fundamentals
- Operational Impacts on DOD Systems
- Space Environmental Services
- Space Debris



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- **Space Environment Fundamentals**
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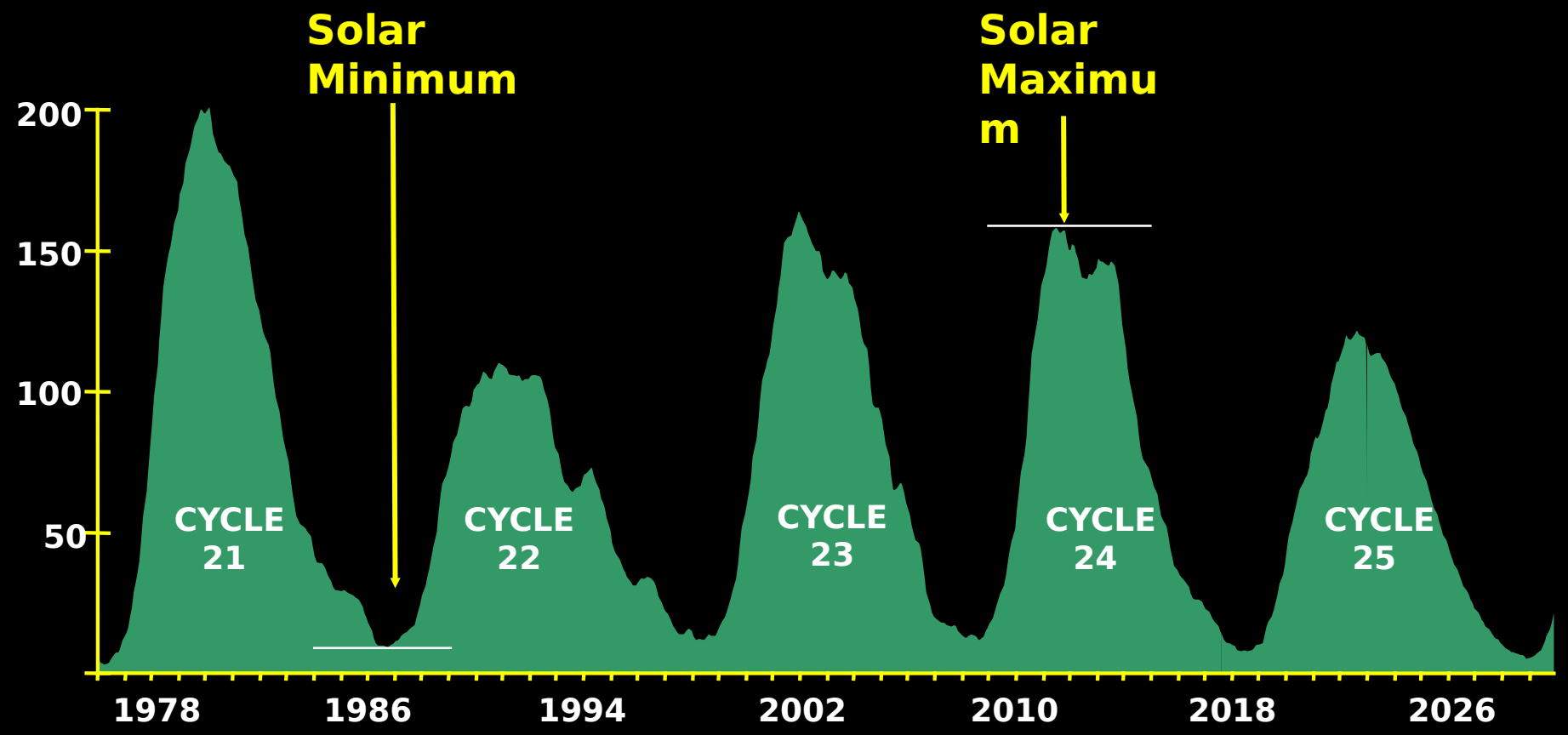
- **Space Debris**

Space Environment Fundamentals

- **Electromagnetic Radiation**
  - **Radio Waves**
  - **Microwaves**
  - **Infrared**
  - **Visible (2%)**
  - **Ultraviolet**
  - **X-rays and Gamma rays**
  - **Cosmic Rays**

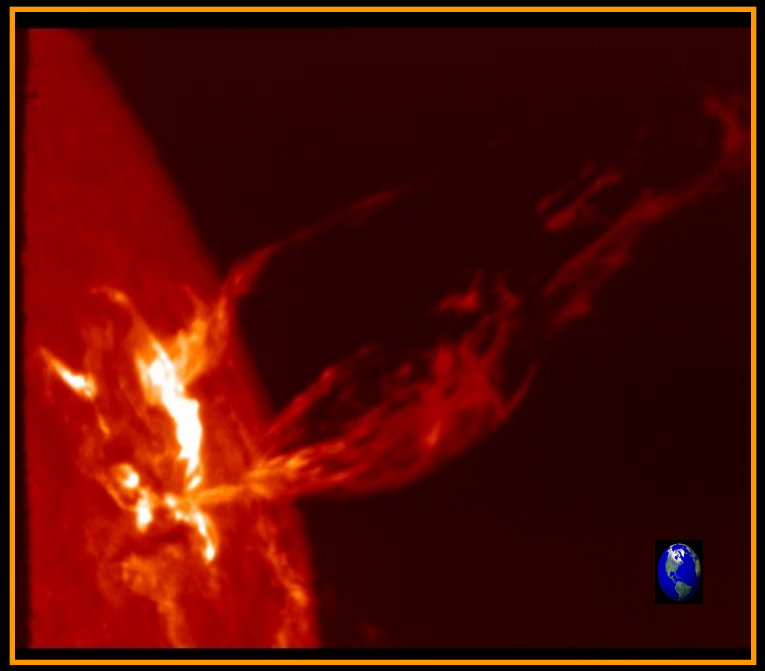
Increase substantially during heightened solar act

The 11-Year Solar Cycle



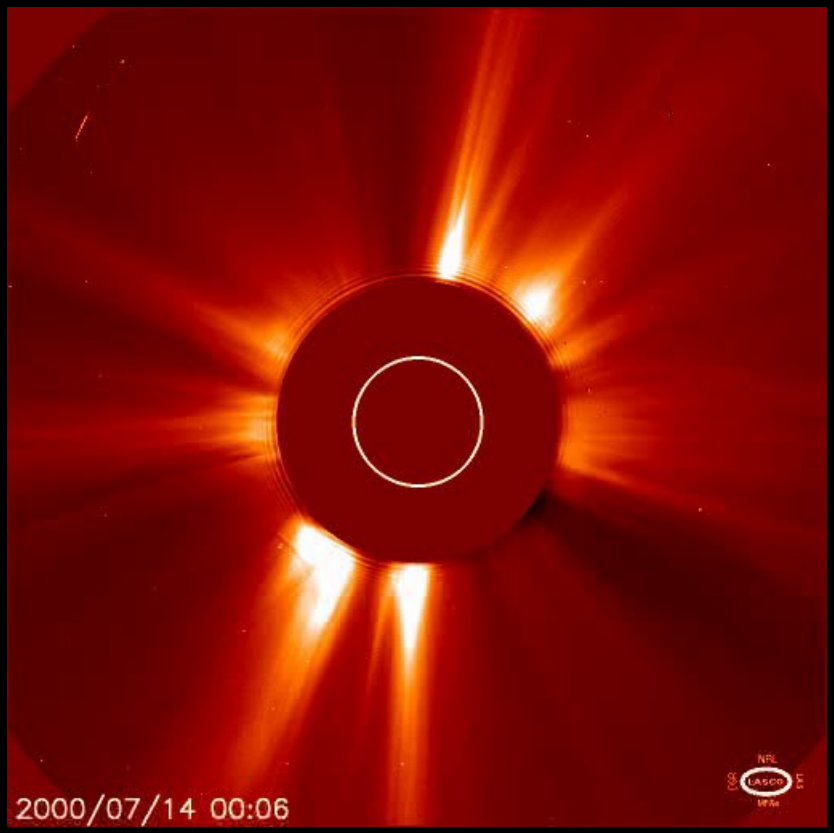
Solar Flare

An explosive release of energy previously stored in intense magnetic fields usually in vicinity of sunspots

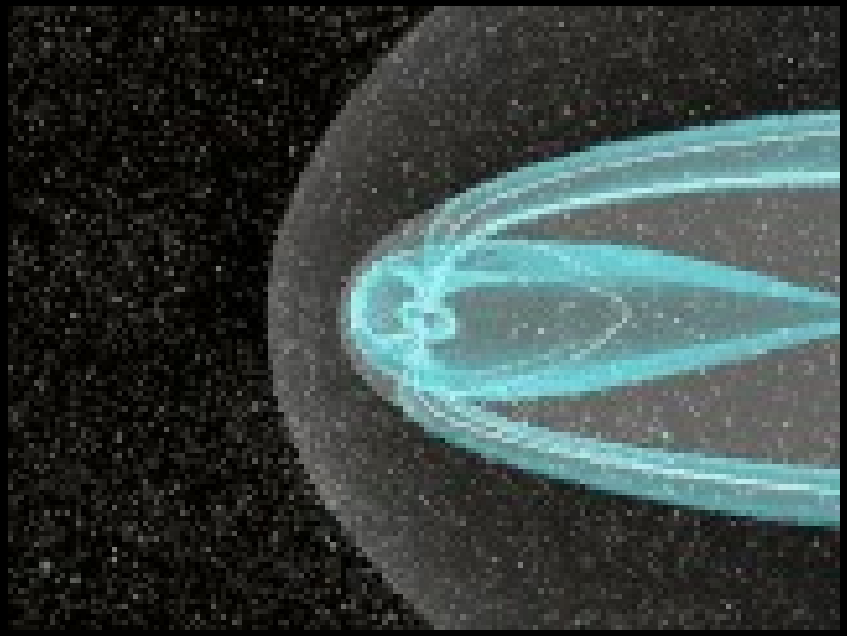


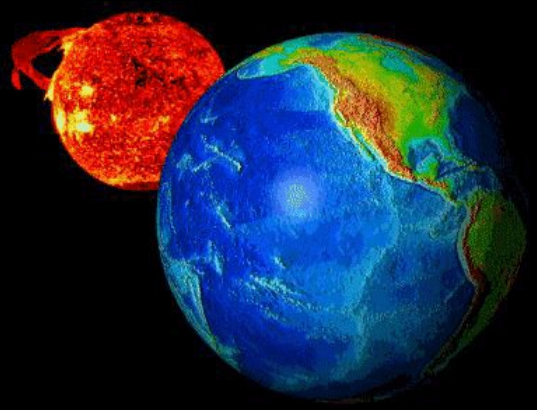
Coronal Mass Ejection (CME)

An eruption of a huge bubble of plasma from the sun's corona often in the vicinity of sunspots (may occur with flares)



Coronal Mass Ejection with resulting Earth effects





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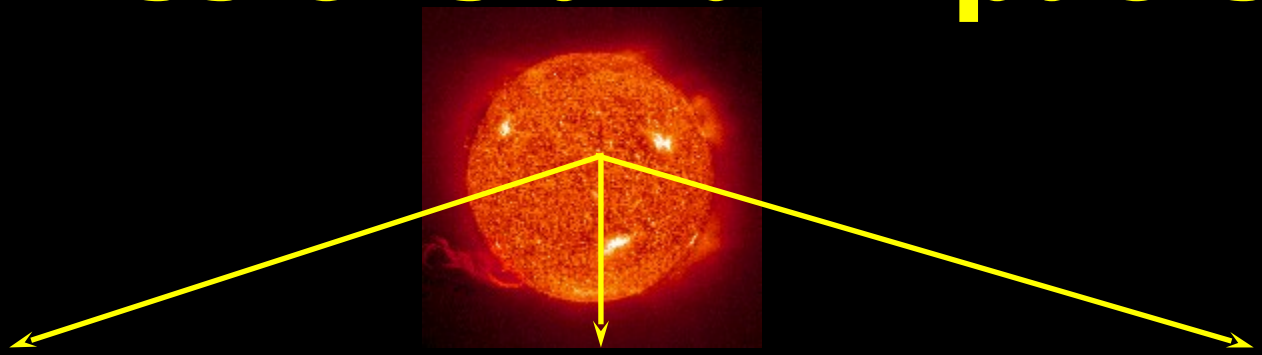
Severe Space Weather Emissions and Impacts



Increased Electromagnetic Radiation
Arrival: 8 min
Duration: 1-2 hours

EFFECTS
- HF Radio Blackout
- SATCOM Interference
- Radar Interference
- Satellite Orbit Decay
- Geolocation Errors

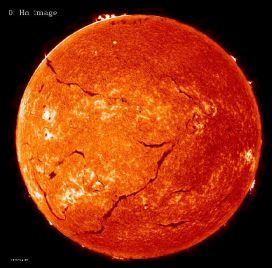
High Energy Charged Particles
Arrival: 15 min to a few hours
Duration: Days

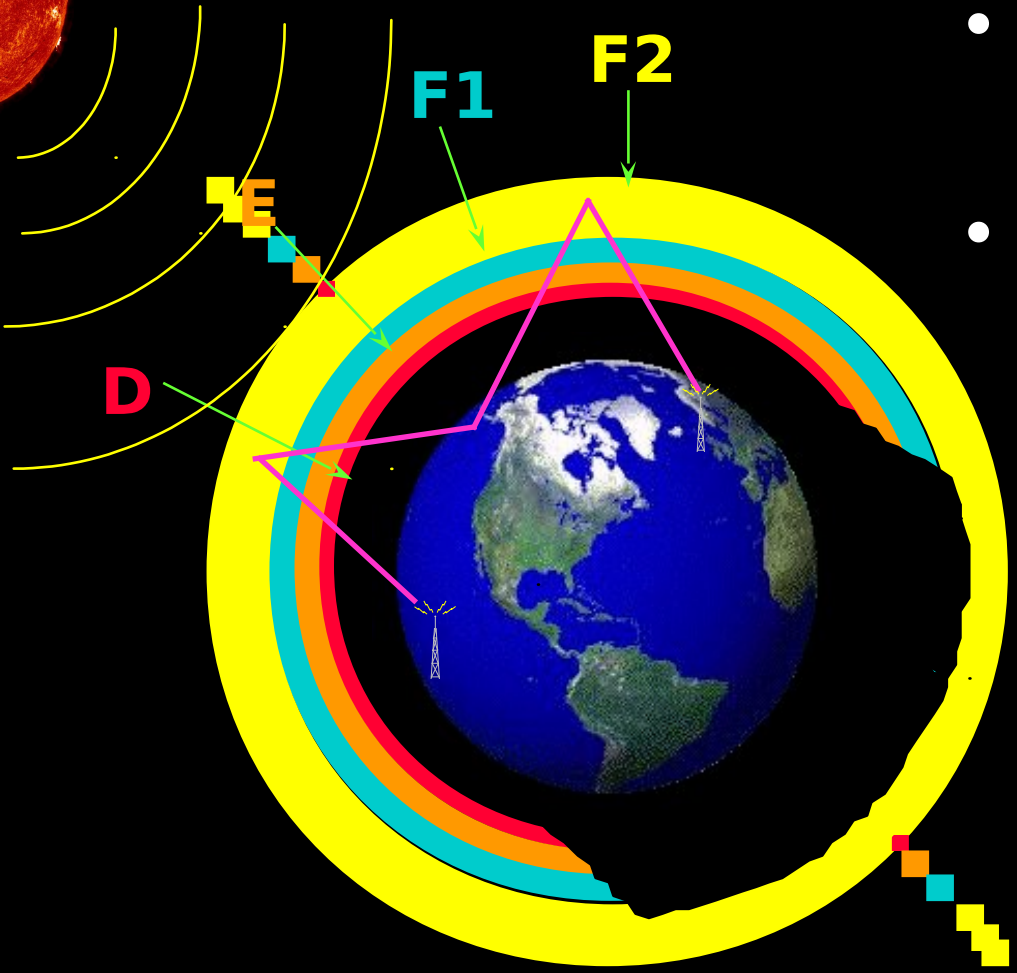
EFFECTS
- Satellite Disorientation
- Spacecraft Damage
- False Sensor Readings
- Launch Payload Failure
- Astronaut Health

Low-Medium Energy Particles
Arrival: 2-3 Days
Duration: Days

EFFECTS
- Geolocation Errors
- SATCOM Disruptions
- Spacecraft Anomalies
- Satellite Orbit Decay
- Radar False Targets

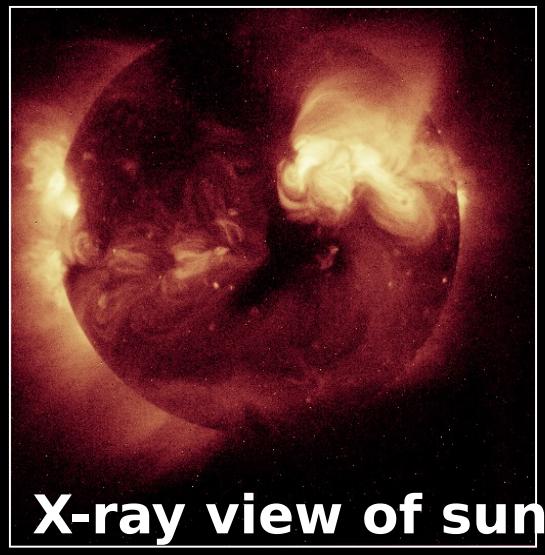
Ionosphere





- ~45 to ~250 miles altitude
- Several layers
  - D (45-55) Inner Ring
  - E (65-75)
  - F1 (90-120)
  - F2 (155-250) Outer Ring

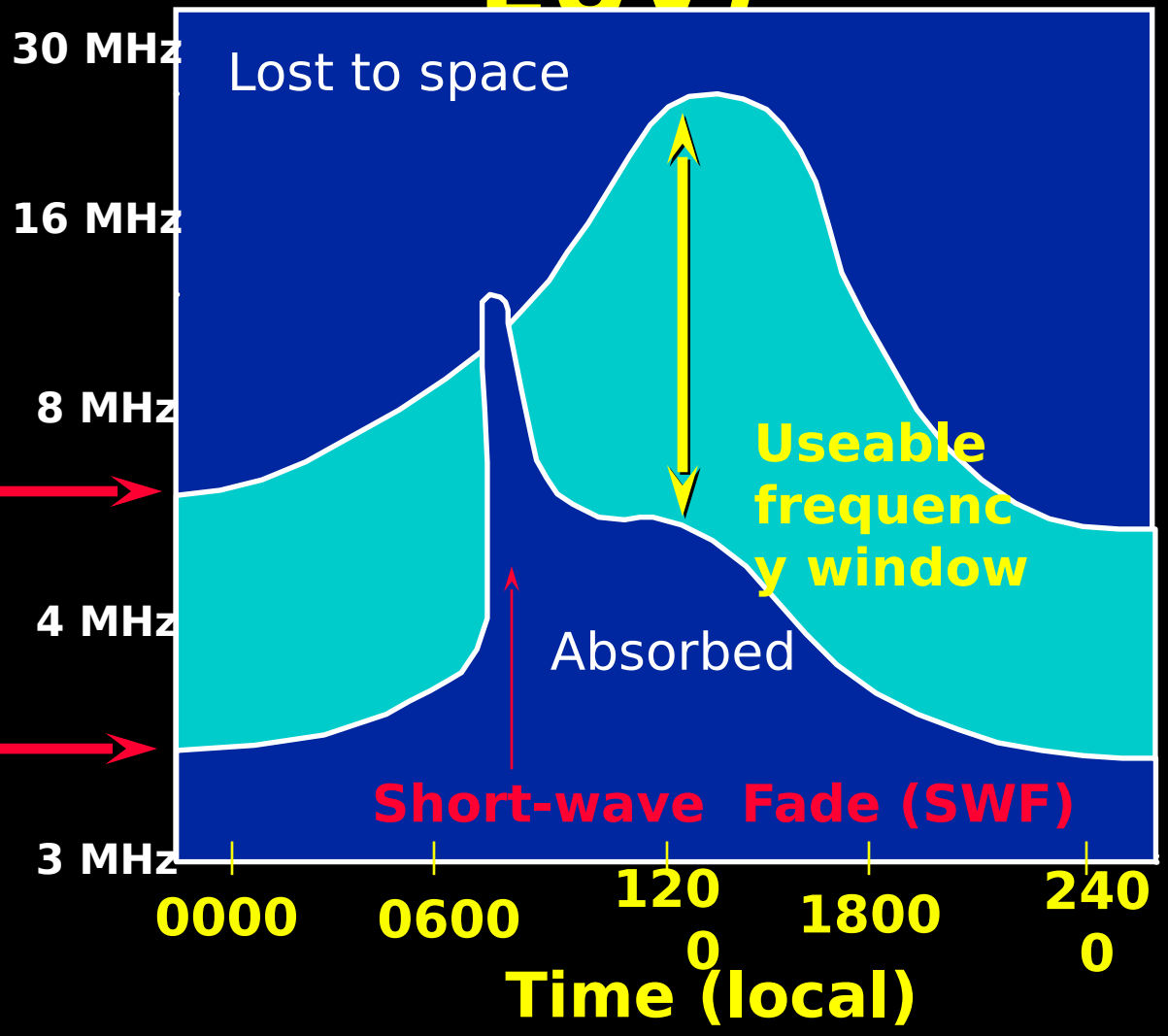
HF Short-wave Fade Event (X-ray, EUV)



X-ray view of sun

Maximum Useable Frequency (MUF) in MHz

Lowest Useable Frequency (LUF) in MHz



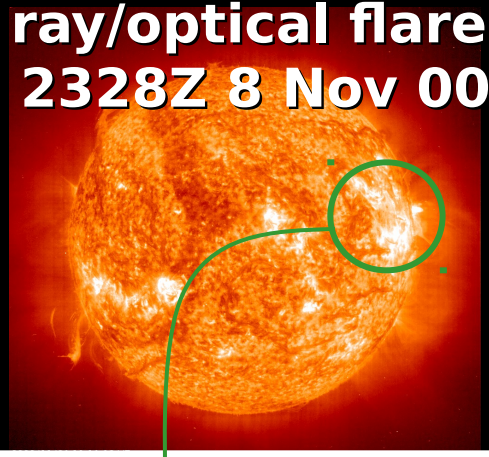
Proton Event Effects

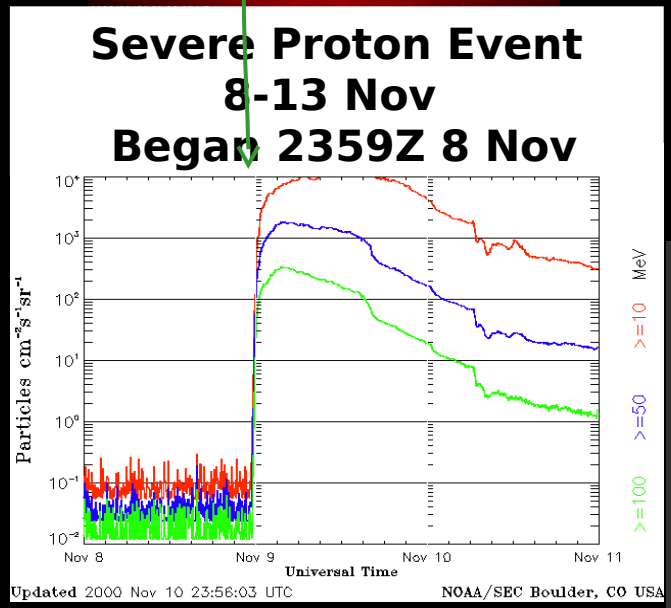
- Satellite Disorientation
- Spacecraft Damage (Single Event Upset)
- SATCOM Interference (Scintillation)
- Scintillation Occurrence
- GPS Navigation Errors (Scintillation)

Proton Event

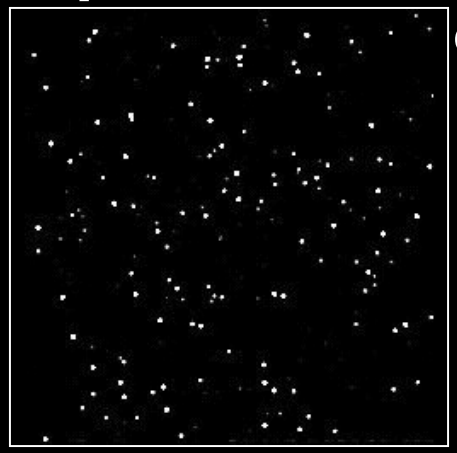
(8-13 November 2000 - Fourth Largest since 1976)

Moderate X-ray/optical flares 2328Z 8 Nov 00





✓ **Star-tracker upset and loss of orientation on NASA's Stardust spacecraft; spacecraft went into safe mode; flight team left spacecraft in safe mode until the end**

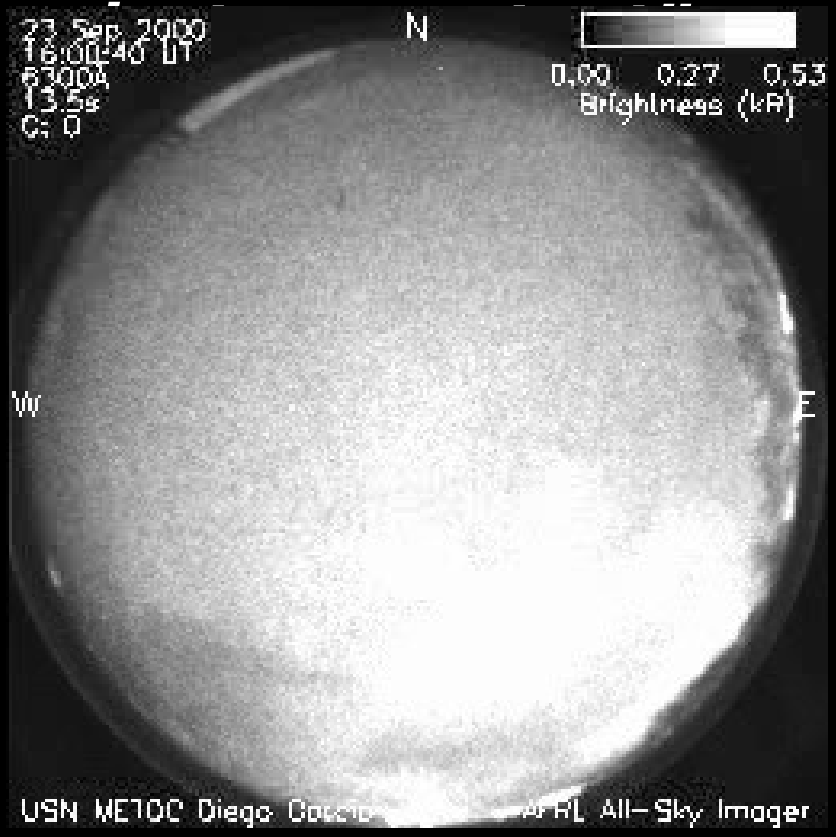


Last image taken before entering safe mode. Image shows hundreds of proton hits as

Image many days later showing guide stars and Saturn, with no proton hits

Scintillation (Definition)

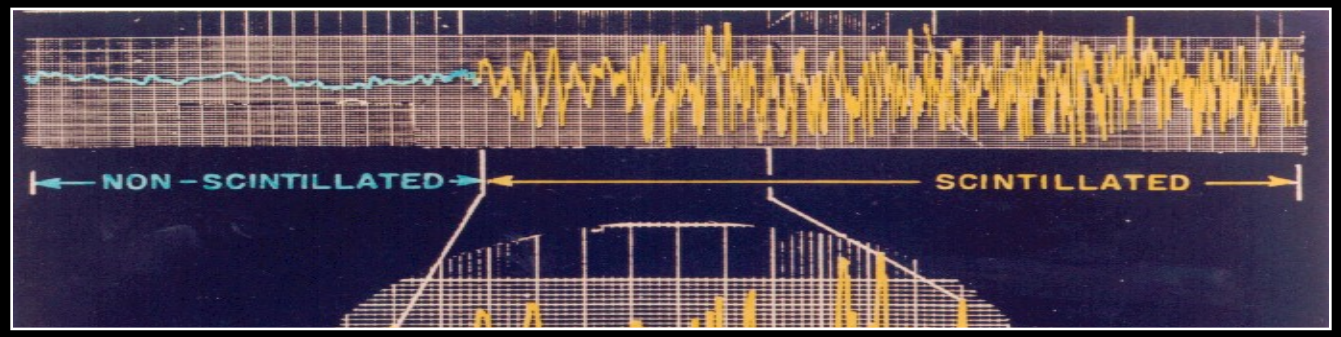
"Scintillation is rapid, usually random, variations in the amplitude, phase or polarization of a radio signal due to local spatial or temporal variations in the ionosphere's

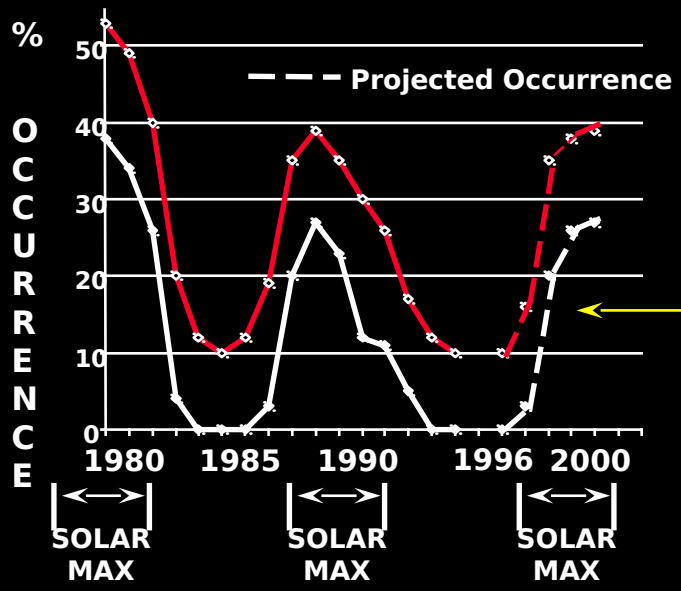


This movie clip, from Diego Garcia on 23 Sep 2000, shows a dark, feather-like cloud crossing the field of view. This feature is a cloud of charged particles responsible for scintillation effects experienced that day. Elapsed time is about two hours.

Scintillation

What it is





UHF SATCOM Outages (Increases up to five- fold during Solar Max)

GPS Navigation Vulnerability (Increases up to four-fold during Solar Max)

How bad it can be

GPS Error Map

For Single Frequency Receivers

PROBLEM:

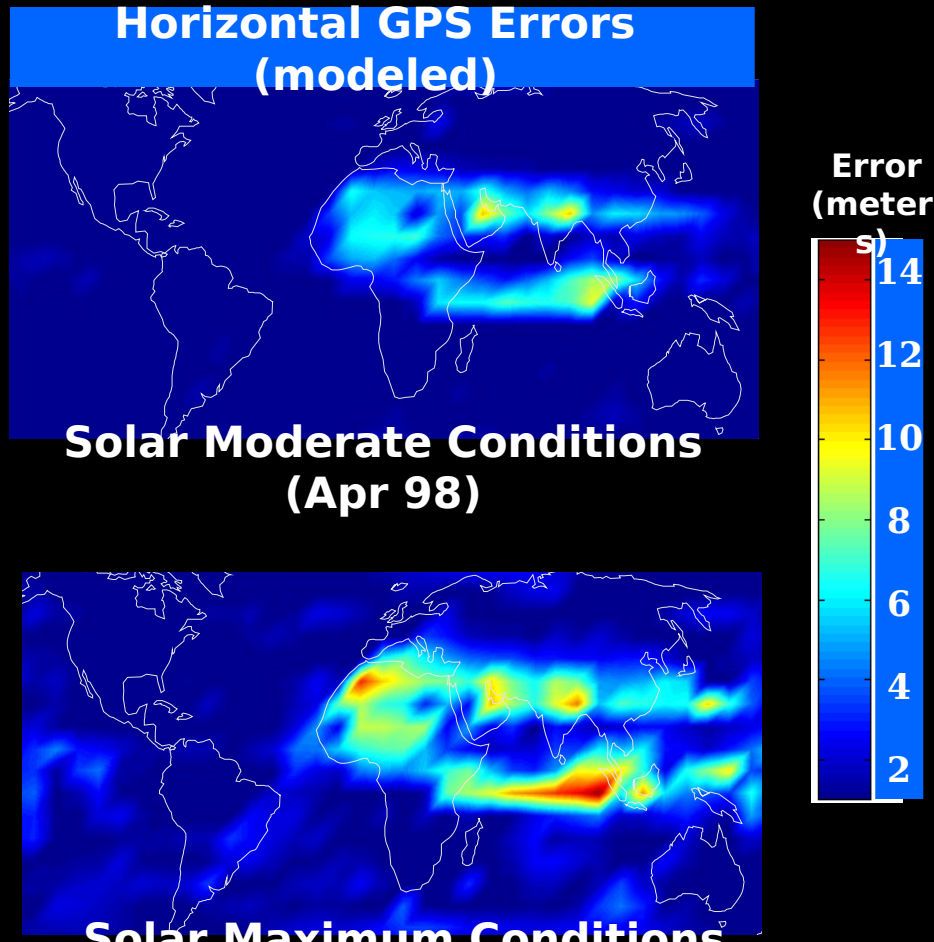
- Ionospheric Correction Algorithm (ICA) Used by All Civilian and Military Single-frequency Receivers Does Not Model Ionosphere Perfectly

SOLUTION:

- Navigation Error Maps Available to the Warfighter in Real-time

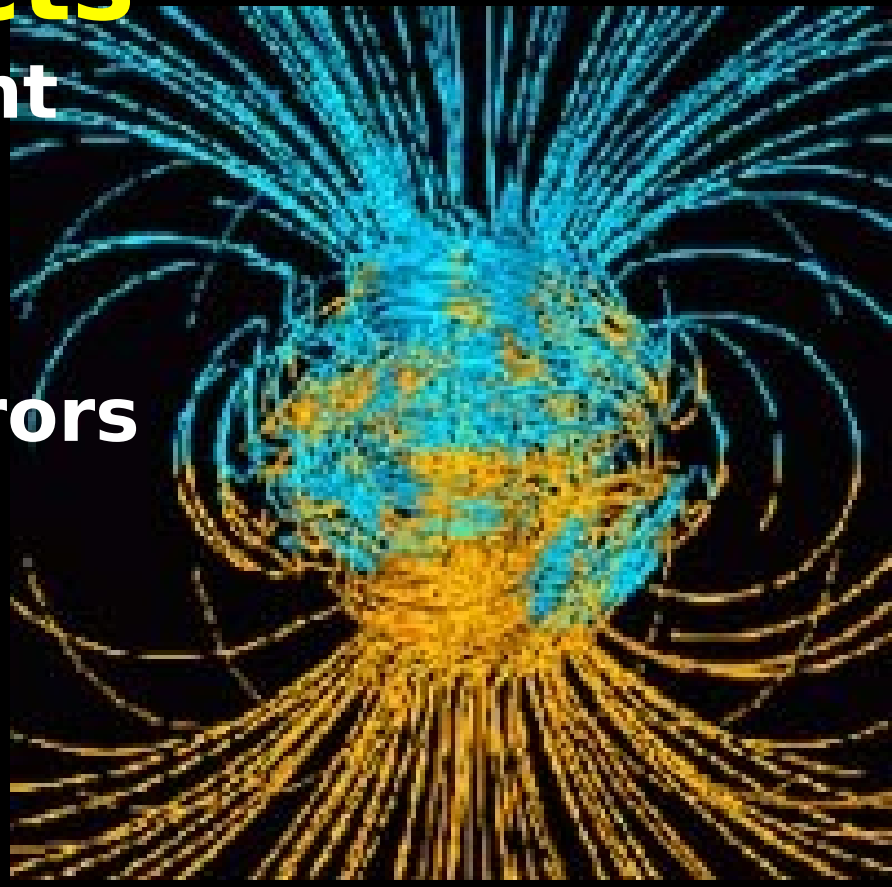
APPROACH:

- Integrate Data-driven PRISM Output With GPS Navigation Algorithm to Calculate Positioning Errors Due to Imperfections in the ICA

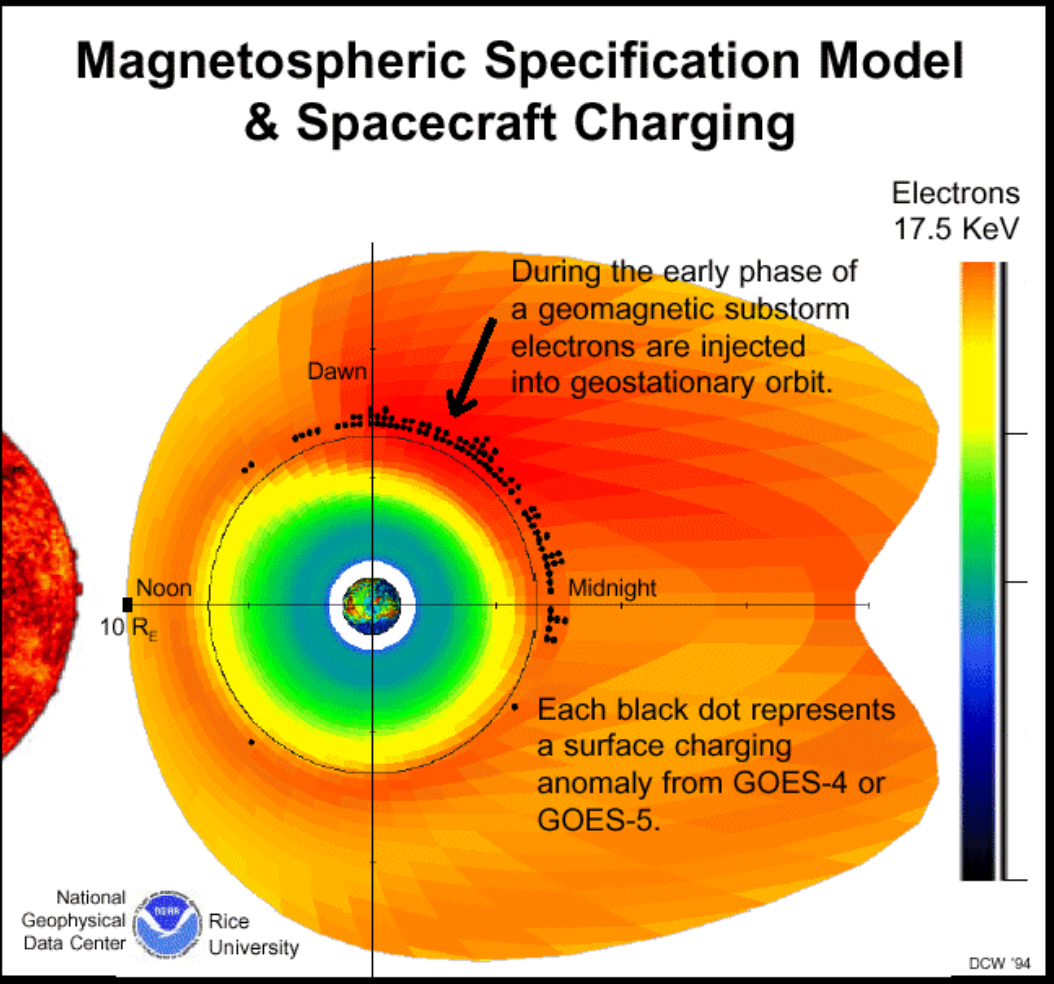


Geomagnetic Storm Effects

- Particle Bombardment
- Spacecraft Charging
- Spacetrack errors
- Launch trajectory errors
- Radar interference
- Atmospheric Drag
- Radiation hazards

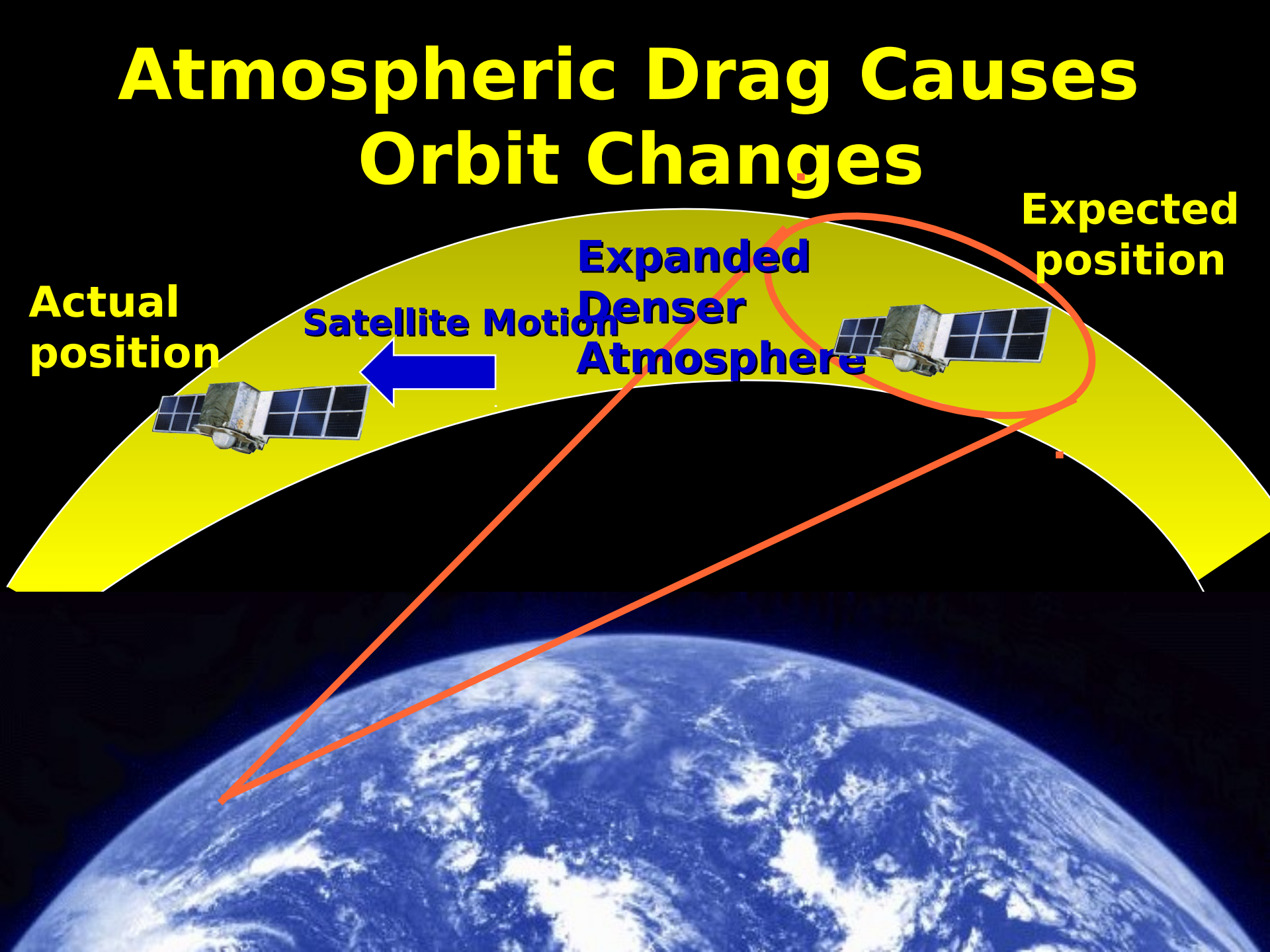


Spacecraft Charging

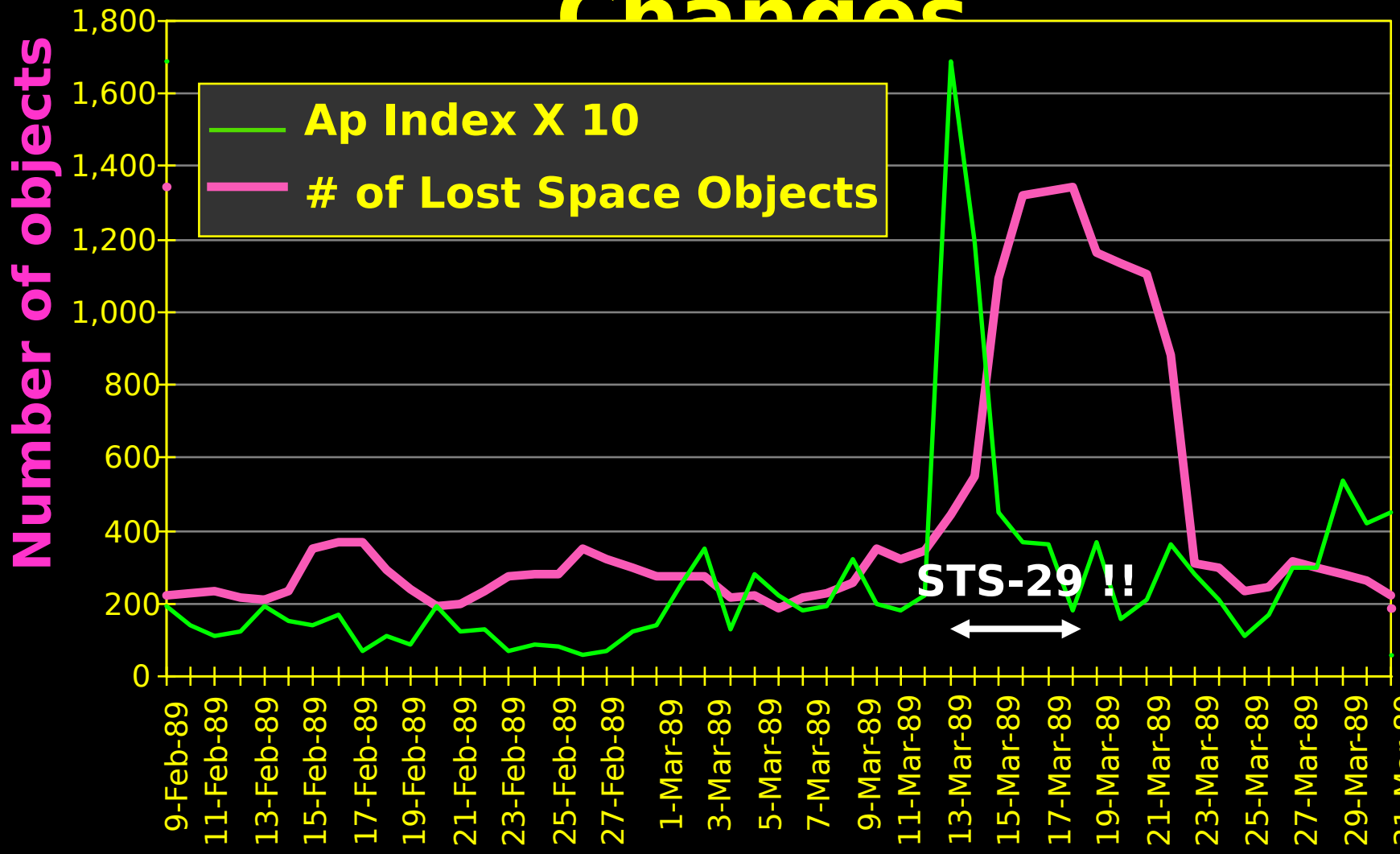


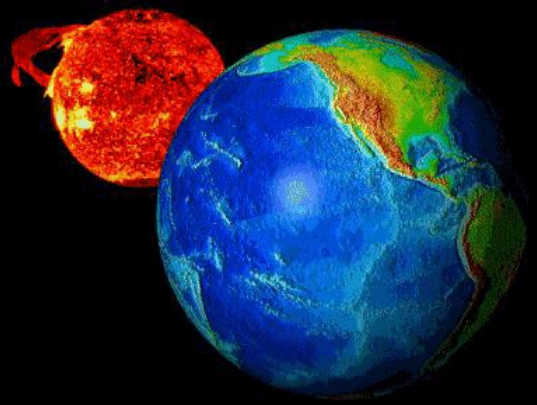
- **Cause** - wake charging, particle bombardment or solar illumination; combined with variations in vehicle shape and materials
- **Effect** - surface or deep charging (depends on particle energy)
- **Result** - delayed electrostatic discharge triggered by change in:
  - Particle environment
  - Solar illumination
  - Vehicle activity such as commanding

Atmospheric Drag Causes Orbit Changes



Effects on Satellite Catalog Due to Drag and Orbital Changes





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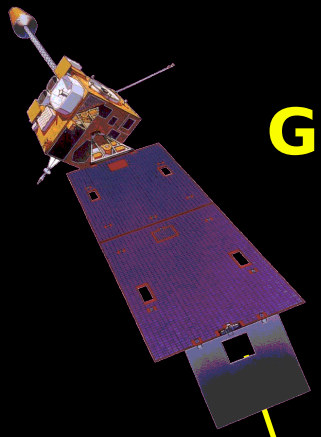
Space Environmental Services

- Rapid event warnings
  - Solar flares (X-ray and radio bursts)
  - Proton events
  - Geomagnetic storms
  - Internal Charging advisory
- Short or long range forecasts
  - General level of solar and geomagnetic activity
  - Specific numerical data or indices
  - Standardized or tailored products
  - On-going or one-time products
- Post-analysis anomaly assessments
  - Radar, communications, and satellites

Space Environment Support



GOES

DSP

DMSP/NOAA

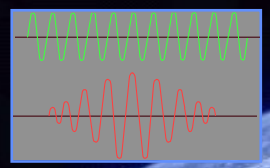
Data Sharing

Coordination

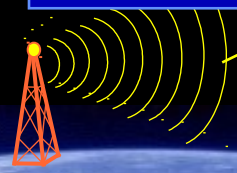
Space Environment Center, Boulder CO

55th Space Weather Squadron, Schriever AFB CO

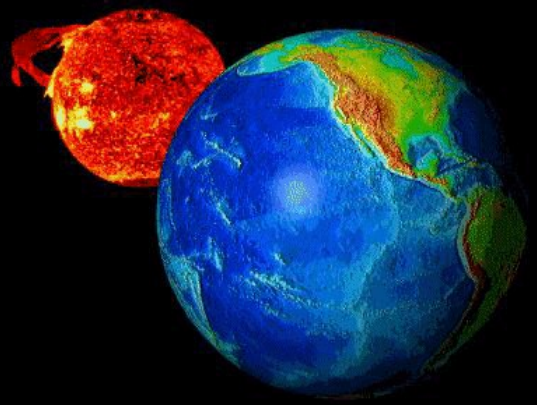
Magnetometers



Ionospheric Sensors



Solar Observatories



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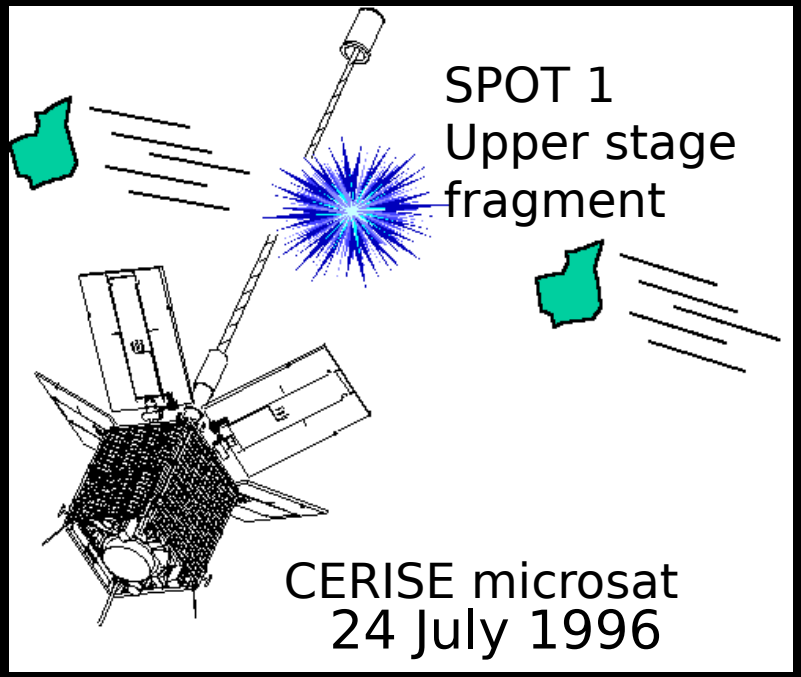
The Debris Problem

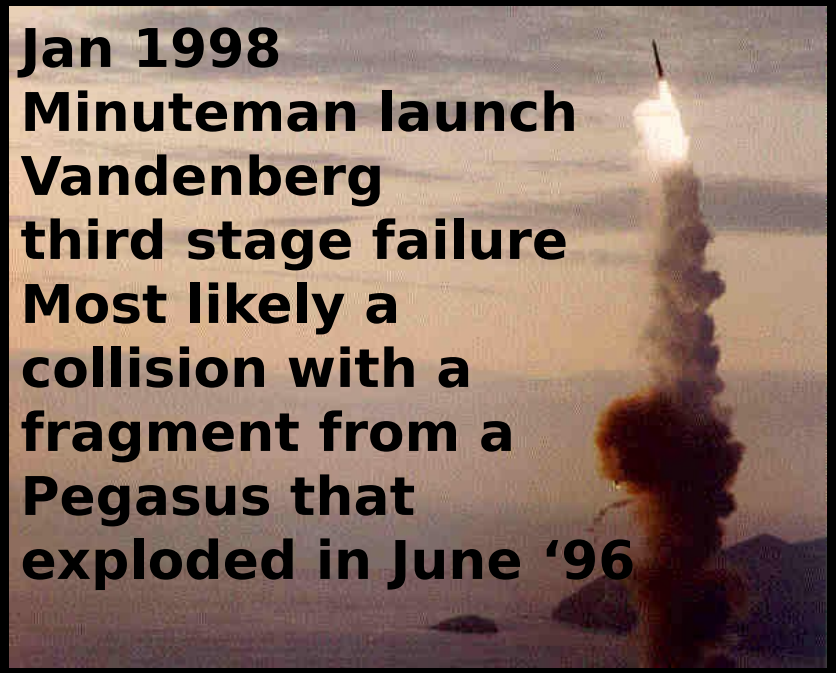
Country of Origin	Payloads	Debris
United States	827	2,900
Russia (& FSU)	1,348	2,558
ESA	36	244
Japan	72	47
China	35	333
France	31	16
Other	479	19
Total	2,828	6,117

* Total, Payloads + Debris = **8,945 objects**
* Operational Spacecraft comprises **~ 7%** of total orbital population **(~626 objects)**

(As of 31 May 01)

Space Debris Consequences





Shuttle orbit must be changed if there i
1 in 10,000 probability of colliding with
object with a diameter of 10cm or more

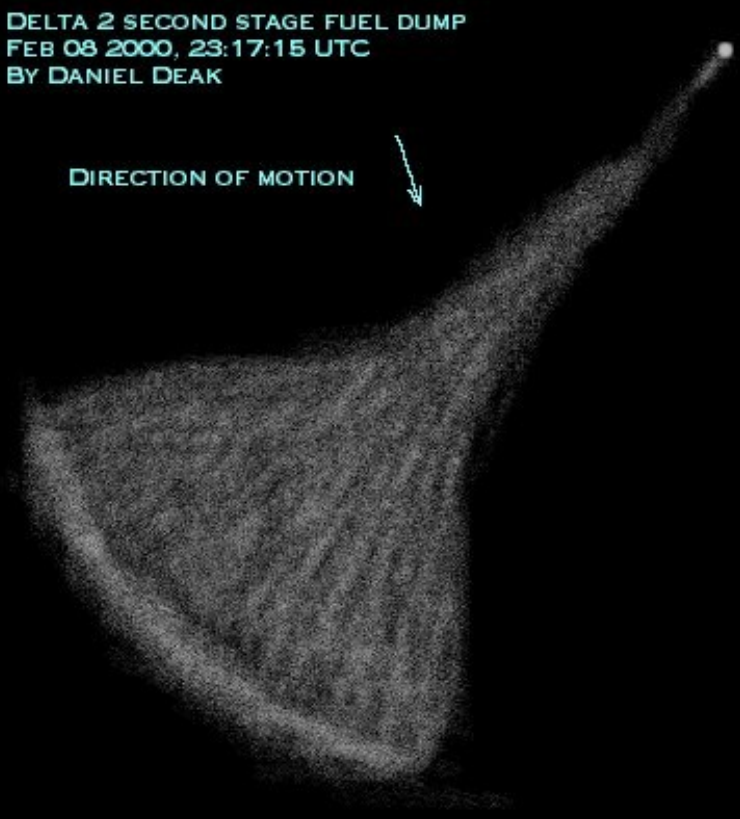
On average, one window per mission mu
be replaced due to impact caused struct
weakening.

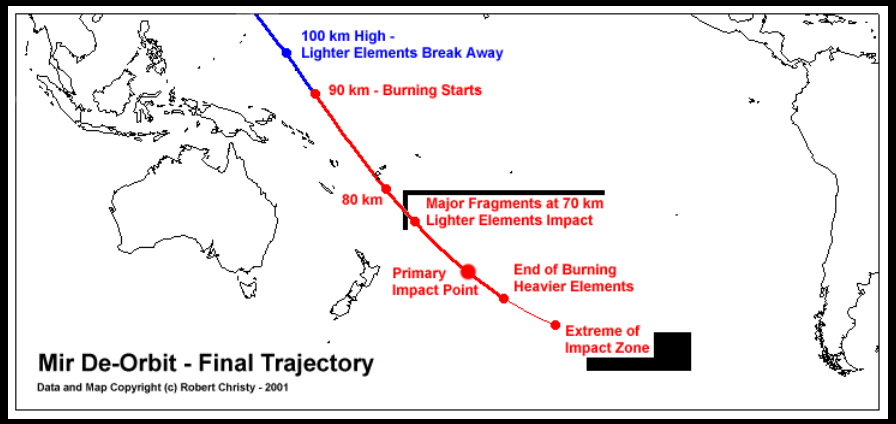
Space Debris Prevention/Removal

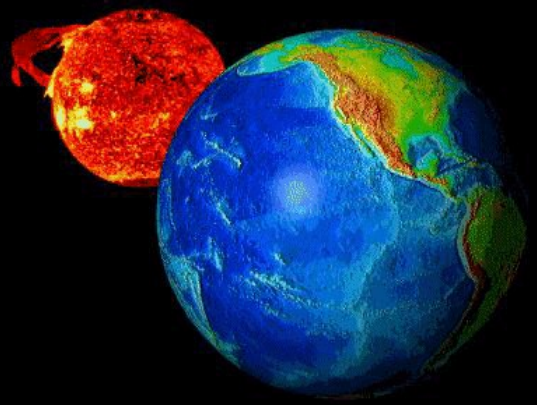
Prevention NASA Safety Standard 1740

Removal processes

- Natural forces
- De-boost
- Retrieval







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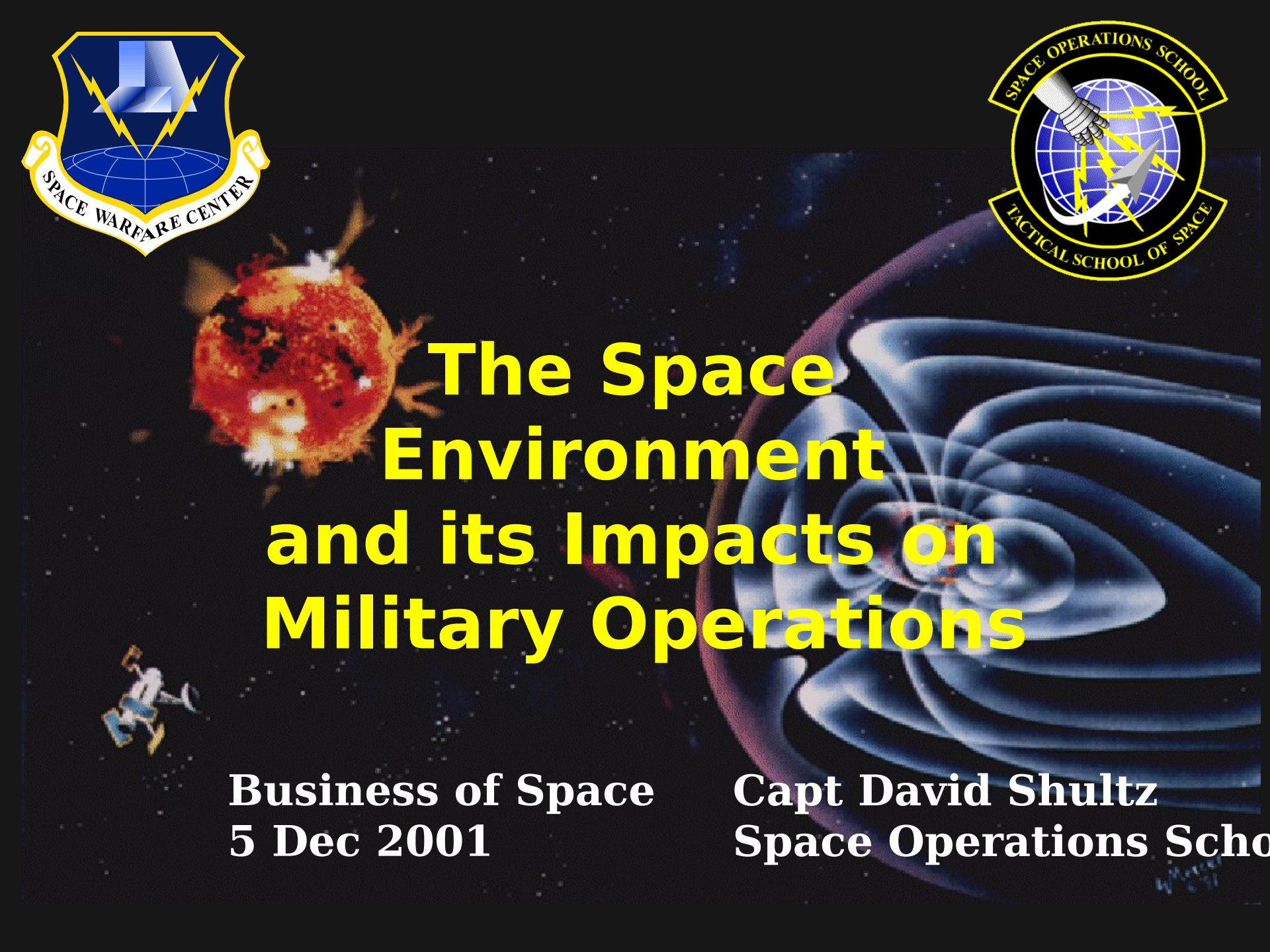


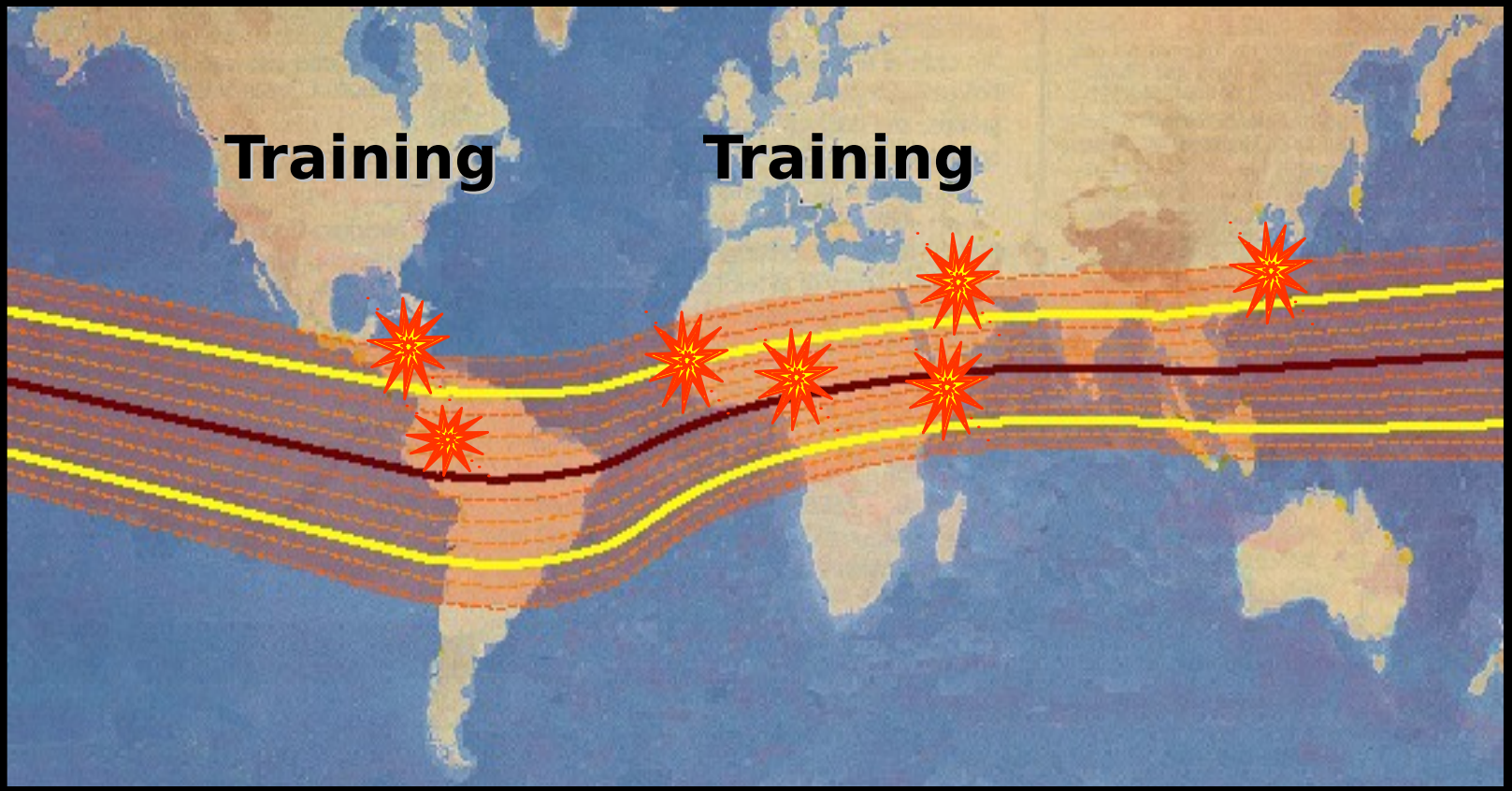
The Space Environment and its Impacts on Military Operations

Business of Space
5 Dec 2001

Capt David Shultz
Space Operations Scho

Ionospheric Scintillation

- Approximately 34% of Earth's Surface is in the affected area



Some Web Sites of Interest

Space Environment Center (SEC) - Boulder CO
http://solar.sec.noaa.gov/index.html

Today's Space Weather
http://www.sel.noaa.gov/today.html

Ionospheric Prediction Service (IPS)
http://www.ips.gov.au/